ABSTRACT

A new shear strengthening technique, designated as Embedded Through-Section (ETS), has been developed to retrofit existing reinforced concrete (RC) elements. This technique calls for holes to be drilled through the beam section; then bars of steel or FRP materials are introduced into these holes and bonded with adhesives to the surrounding concrete. When concrete cover has not the bond and strength requisites to guarantee a strengthening effectiveness for the Externally Bonded and Near Surface Mounted techniques, ETS strategy can be a competitive alternative since it mobilizes the beam’s concrete core which is, generally, free of damage. To explore the potentialities of the ETS technique for the shear strengthening of RC beams, an experimental program was carried out, composed of RC T-cross section beams strengthened in shear by using steel bars and ETS CFRP rods. The research was focused on the evaluation of the ETS efficiency on beams with different percentage of existing internal transverse reinforcement ($\rho_{sw}=0.0\%$, $\rho_{sw}=0.1\%$ and $\rho_{sw}=0.17\%$) and on the study of the interaction effect between ETS bars and existing steel stirrups. The influence of the inclination and shear strengthening ratio of ETS configurations on the shear strengthening efficiency was also evaluated. The good bond between the strengthening ETS bars and the surrounding concrete allowed the yield initiation of the ETS steel bars and the attainment of high tensile strains in the ETS CFRP rods, leading to significant increase in shear capacity (up to 136\%). The attained level of shear capacity was strongly influenced by the inclination of the ETS bars and the percentage of internal transverse: inclined ETS bars provided higher increase of shear resistance than vertical ones.

The predictive performance of two analytical models to calculate the ETS strengthening contribution was assessed by using the experimental results. The first model follows an empirical approach (experimental-based approach), while the second model takes into account the physical and mechanical principles of the technique (mechanical-based approach).

The predictive performance of a numerical model is evaluated simulating the tested beams strengthened with ETS technique. The strategy to simulate the crack shear stress transfer in a fixed smeared crack based finite elements program is crucial to correctly predict the deformational and cracking behavior of RC elements that exhibit shear failure. An alternative strategy to shear retention function is presented in this work, based on the adoption of a bilinear softening diagram ($t_i^\sigma - \gamma_i^\sigma$) for modelling the sliding component of the crack constitutive law. The parameters influencing the $t_i^\sigma - \gamma_i^\sigma$ diagram are individually investigated and analyzed as a function of the mechanical and geometrical properties of the tested beams. A simple rule to estimate the values of the $t_i^\sigma - \gamma_i^\sigma$ diagram is provided and its predictive performance is assessed.